SPRAGUE®
THE MARK OF RELIABILITY

TED-507

OPERATING MANUAL

FOR THE

MODEL 2W1

CAPACITANCE METER

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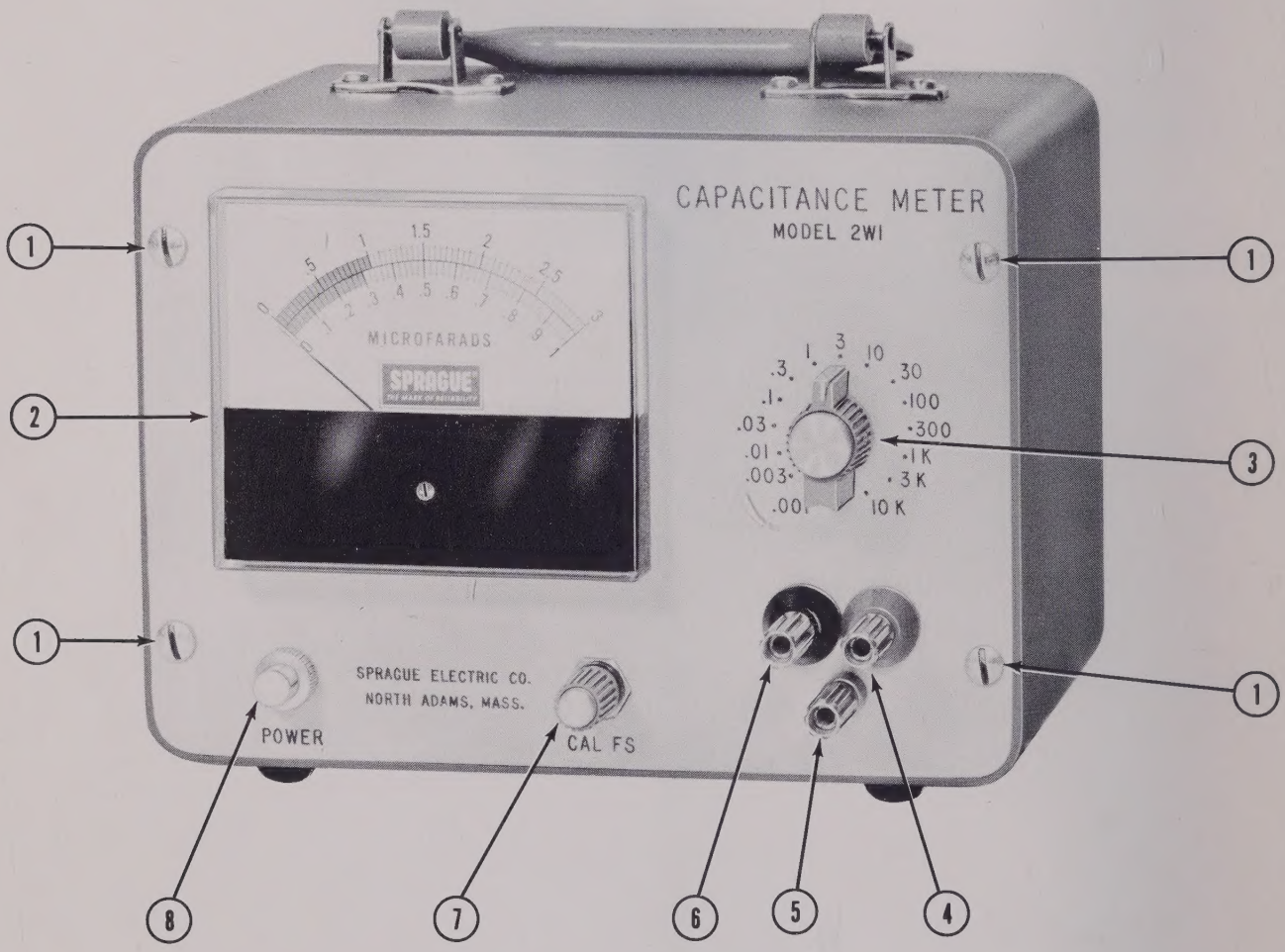
SPRAGUE ELECTRIC COMPANY
North Adams, Massachusetts



1. *Front panel mounting screw*
2. *Microfarad meter*
3. *Microfarad range switch*
4. *Red input terminal*
5. *Silver input terminal*
6. *Black input terminal*
7. *Calibration control*
8. *Power switch/pilot light*

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Operating Manual for the Model 2W1 Capacitance Meter

1. Introduction

1.1 General. The Model 2W1 Capacitance Meter is a wide-range instrument that offers good accuracy as well as the simplicity and high-speed direct-reading required for service work, production testing, and incoming inspection.

1.2 Operating Frequency. The Model 2W1 Capacitance Meter utilizes a self-contained test voltage source and amplifier for operation at either 50 Hz or 60 Hz. At either frequency the meter is direct-reading in microfarads.

1.3 Application. The Model 2W1 is designed for the measurement of all types of capacitors, including low-voltage electrolytics.

1.4 Specifications. Performance specifications and other data pertaining to the Model 2W1 Capacitance Meter are given in the Appendix.

1.5 Schematics. Partial schematics of circuits being discussed are shown with the text related to them. The complete schematic of the Model 2W1 Capacitance Meter is shown in Figure 8.

2. Instrument Circuits

2.1 The 2W1 Capacitance Meter circuitry consists of the test voltage source and amplifier power supply, the range-selection circuit, and the amplifier/metering circuit.

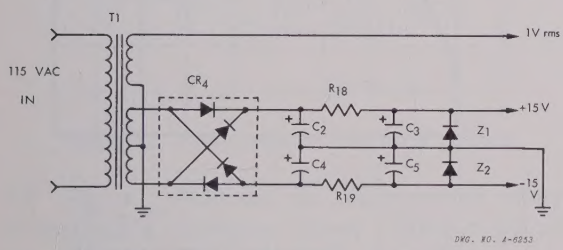

Figure 1. Test voltage source and amplifier power supply.

2.2 Test Voltage Source and Amplifier Power Supply (Figure 1). The test voltage source consists of one secondary winding of transformer T_1 which has an output voltage of 1 volt rms when the instrument is operated at 115 volts rms line voltage. The output voltage of this winding is directly proportional to the line voltage. The amplifier power supply is a full-wave bridge (CR_4) whose output is filtered and regulated at ± 15 volts.

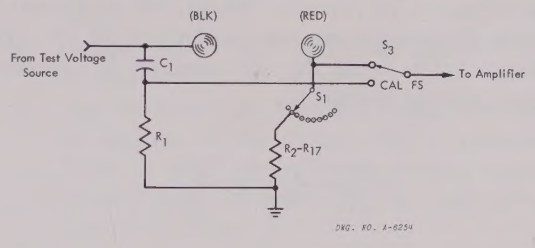

Figure 2. Range-selection circuit

2.3 Range-Selection Circuit (Figure 2). The basic range-selection circuit consists of range resistors R_2 through R_{17} selected by range-switch S_1. The "CAL FS" switch (S_3) selects the calibrating resistor R_1 and the calibrating capacitor C_1.

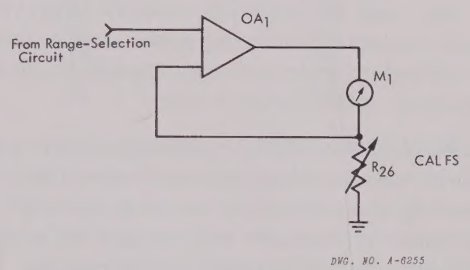

Figure 3. Amplifier/metering circuit

2.4 Amplifier/ Metering Circuit (Figure 3). The basic circuit of the solid-state amplifier/metering circuit is an operational amplifier coupled to an output metering circuit. Resistor R_{26} adjusts the amplifier gain.

3. Input Connections

3.1 The capacitor under test may be connected to the Model 2W1 Capacitance Meter by either a 2 or 3 terminal connection. The choice depends upon the remoteness of operation, as well as the electrical environment, physical construction, and capacitance rating of the unknown capacitor.

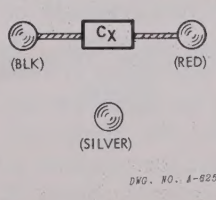

Figure 4. 2-Terminal connection

3.2 The 2-Terminal Connection (Figure 4). The 2-terminal connection is used when the unit under test has a capacitance value high enough and when the electrical environment of the unit under test is sufficiently benign to prevent measurement error due to stray capacitances and stray pickup voltages. These limits cannot be precisely defined, but in general 2-terminal measurements are satisfactory for all capacitance values when the test capacitor is connected directly to the instrument.

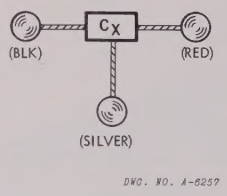

Figure 5. 3-Terminal Connection

3.3 The 3-Terminal Connection (Figure 5). The 3-terminal connection is used for remote measurements if the capacitor under test has a floating metallic case that must be grounded to avoid stray voltage pickup, and/or the connecting cables must be shielded to avoid pickup if the unknown capacitor's electrical environment is sufficiently hostile.

3.4 Stray Capacitance. Although stray capacitances between the black post and its grounded shield will not affect measurement accuracy, excessive stray capacitances between the red post and its grounded shield do affect instrument measurements. However, this stray capacitance can be as high as 50% of the full scale μF value on any range without introducing significant error.

4. Operation

4.1 Connect to Power Source. With the power cord, connect the meter to a 105-125 volt, 50-60 Hz outlet. If the a-c outlet does not have a mating receptacle for the 3 conductor plug, use the three-to-two wire adapter that comes with the instrument.

NOTE: Whether the outlet is 2 conductor or 3 conductor, a good ground connection is essential for safety; either to the short wire of the adapter, or to the U-shaped grounding prong of the power cord plug.

4.2 Apply Power. Apply power by depressing the button labeled *POWER* located in the lower left-hand corner of the instrument. The button should light, indicating that power is being applied. The unit is now ready for immediate use.

4.3 Attach Unknown Capacitor. Connect the capacitor which is to be tested to the instrument.

a. For 2 terminal measurements, one capacitor lead is connected to the red post, and the other lead is connected to the black post (Figure 4).

b. For 3 terminal measurements, one capacitor lead is connected to the red post, and the other lead is connected to the black post. The floating metallic shield or case of the capacitor and/or the connecting cable shields are connected to the silver ground post (Figure 5).

4.4 Select Range. Rotate range switch until an on-scale meter indication is obtained.

4.5 Calibrate Meter. Depress *CAL FS* control and adjust until meter indicates full scale. Release control without further adjustment.

4.6 Read Meter. Locate proper scale and decimal point by referring to the range switch. For example: if a particular test capacitor results in a meter indication of 0.5 with the range switch set at *100*, the value of the capacitor being tested is 50 μF.

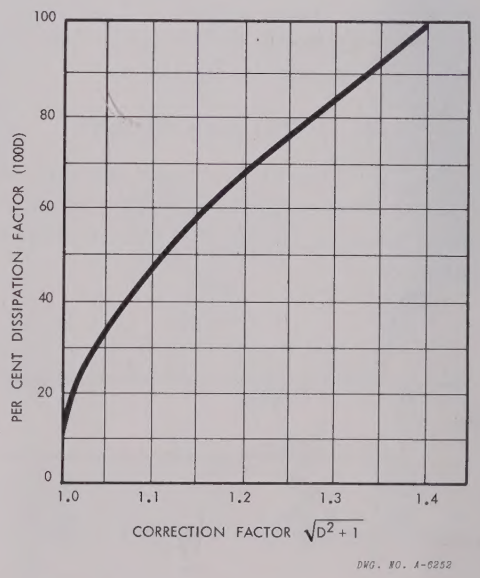

Figure 6. Dissipation factor correction

a. If the dissipation factor of the capacitor under test exceeds 10% (D = 0.1), a correction should be made in the meter indication by multiplying the meter reading by $\sqrt{D^2+1}$ (see Figure 6).

5. Remote Measurements

5.1 The Model 2W1 Capacitance Meter may be used for measuring capacitances at remote locations without degrading measurement accuracy if the following procedure is used.

5.1.1 Connect leads of the desired length to the red and black posts.

a. Use shielded cables, if desirable, to avoid stray pickup voltages and/or stray capacitance.

b. Connect the instrument ends of both cable shields to the instrument silver ground post.

c. Since both cable shields are grounded at the instrument, they may also be grounded at the test capacitor if it is found that this is desirable.

d. The maximum conductor-to-shield capacitance of the cable which is connected to the red post should not exceed 50% of the full scale μF value on the range being used.

6. Polarizing Voltages

6.1 A d-c polarizing voltage is not normally needed with the Model 2W1 Capacitance Meter because never more than 1V rms is applied across the capacitor under test. In those few instances where a polarizing voltage is desired, the preferred source is a wet cell or dry cell, although a rectified a-c power supply may be used.

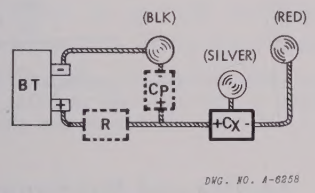

Figure 7. Application of Polarizing Voltage

6.2 Figure 7 illustrates the recommended method of applying a polarizing voltage. When a polarizing voltage is used, follow these instructions:

a. Connect the negative output terminal of a d-c power supply to the black post.

b. Connect the positive output terminal of the d-c power supply to the positive terminal of the capacitor which is to be tested. If necessary, in order to limit the d-c current through the instrument, insert a resistor between the test capacitor and the power supply. See also, paragraph 6.2f.

c. Connect the test capacitor negative terminal to the red post.

d. If necessary, connect a suitable capacitor, observing polarity, between the power supply negative output terminal and the test capacitor positive terminal. See also, paragraph 6.2g.

e. Operate the Model 2W1 Capacitance Meter as instructed in paragraph 4.

f. The maximum d-c polarizing voltage that may be applied to the Model 2W1 Capacitance Meter is 600 volts. The maximum current permissible is determined by the range switch setting as follows:

Table I

Setting of range switch	Maximum current permissible (in mA)
.001	1.5
.003	3
.01	4
.03	7
.1	13
.3	20
1	40
3	70
10	130
30	220
100	570
300	1000
1K	1000
3K	1000
10K	1000

g. Since the d-c power supply is in series with the instrument's test voltage source, the 50-60 Hz a-c impedance of the power supply must be as low as possible in order to retain instrument accuracy. If this impedance is greater than 25 $\Omega \div$ the full-scale μF value on the range being used, it must be reduced by connecting a capacitor (C_p in Figure 7) of at least 100 times the full scale value, and of at least the voltage rating of the test capacitor, between the power supply negative output terminal and the test capacitor positive terminal, observing proper polarity. Because both power supply terminals are floating in this circuit, each terminal of the power supply and the capacitor C_p must be isolated from ground. If an isolated battery is used for the power supply (BT in Figure 7), no problem exists. However, if a rectified a-c power supply is used, both output terminals must each have at least 30 MΩ impedance to ground.

7. Resistance and Inductance Measurements

7.1 General. The Model 2W1 Capacitance Meter may be utilized for resistance and inductance measurements through the simple calculations described below.

7.2 Resistance. With the unknown resistor connected between the red and the black posts, $R_x = \frac{2490}{\mu F}$, where uF is the capacitance value indicated by the meter.

7.3 Inductance. Similarly, $L_x = \frac{7.03.}{\mu F}$

8. Semi-Automatic Operation

8.1 The Model 2W1 Capacitance Meter may be converted to semi-automatic operation by removing the original output meter and substituting a 0 to 50 μA d-c, 2,500Ω electronic limit detector or control meter.

9. Calibration

9.1 General. Although there are several methods of verifying the accuracy of the Model 2W1 Capacitance Meter, any calibration procedure should include checking the following:

a. The accuracy and linearity of the amplifier/metering circuit.
b. The accuracy of the range selection circuit.

9.2 Example. The following procedure is one acceptable method of verifying the accuracy of the Model 2W1 Capacitance Meter. Equipment required for this procedure are:

a. Four precision capacitance standards, such as the Sprague No. 280W Series, with nominal values of 0.001 μf, 0.002 μf, 0.005 μf, and 0.01 μf.

b. One precision resistance decade, covering the range of 1 Ω to 300 KΩ.

9.2.1 Calibration of the Amplifier/Metering Circuit.

a. Set the range switch to *.001*.
b. Connect the 0.001 μF capacitance standard to the red and the black posts.
c. Depress and adjust the *CAL FS* control until the meter indicates full scale.
d. Upon releasing the *CAL FS* control, meter should read 1.0 $\pm$ tolerance. Tolerance is 3% + the accuracy of the capacitance standard in per cent.

Example: $C_{standard}$ = 0.001 μF $\pm$ 0.1%
Meter = 1.0 $\pm$ (3 + 0.1)% = 1.0 $\pm$ 3.1%
= 0.969 to 1.031

NOTE: It is assumed that the dissipation factor of the capacitance standard is less than 10%.

e. Repeat steps a, b, c, and d with the 0.002 μF capacitance standard on the *.003* range. The meter should indicate between 1.909 and 2.091.

f. Repeat with the 0.005 μF and the 0.01 μF standards on the *.01* range. The meter should indicate between 0.469 and 0.531 for the 0.005 standard and bwtween 0.969 and 1.031 for the 0.01 μF standard.

9.2.2 Calibration of the Range Selection Circuit.

a. Set the resistance decade to 300 KΩ and connect it between the red and the black posts.
b. Set the range switch to *.01*.
c. Without depressing, adjust the *CAL FS* control for full-scale meter indication.
d. Without further adjustment of the *CAL FS* control, set resistance decade to 100 KΩ and the range switch to *.03*.
e. The meter should read 3.0 $\pm$ tolerance. Tolerance is 1% + the accuracy of the resistance decade in per cent.

Example: $R_{standard}$ = 100 KΩ $\pm$ 0.1%
Meter = 3.0 $\pm$ (1 + 0.1)% = 3.0 $\pm$ 1.1%
= 2.967 to 3.033

f. Repeat steps *d* and *e*, using the range switch and decade settings given below.

Table II

Range Switch Setting	Decade Setting
.1	30KΩ
.3	10KΩ
1	3KΩ
3	1KΩ
10	300Ω
30	100Ω
100	30Ω
300	10Ω
1K	3Ω
3K	1Ω
10K	1Ω

DO NOT USE EXCESSIVE ERROR

USE CAPACITOR

NOTE: Meter indication should continue to be 1.0 or 3.0 $\pm$ tolerance (0.989 to 1.011 and 2.967 to 3.033), depending on range, except on 10K range where indication should be 0.289 to 0.311.

10. Service and Maintenance

10.1 Preventive Maintenance. All contact surfaces of the range switch should be cleaned and lubricated periodically, depending upon the amount of usage. The recommended lubricant is Cramolin compound, manufactured by Caig Laboratories, 46 Stanwood Road, New Hyde Park, New York, 11040, U.S. of America.

10.2 Malfunctions. The Model 2W1 Capacitance Meter is designed and constructed to give long, trouble-free operation, but occasional malfunctions may occur. Most difficulties can be corrected by using the calibrating instructions contained in this manual (Section 9) and following normal trouble-shooting procedures. Procedures for returning the instrument to the factory are contained in the warranty located on the inside back cover.

APPENDIX

Specifications and Performance Characteristics

1. Size

1.1 6" high x 8½" wide x 5" deep, excluding controls and handle.

2. Net Weight

2.1 8 pounds.

3. Mounting

3.1 The instrument is mounted in a metal cabinet, with a molded plastic handle, in standard Sprague blue finish. The meter panel is gray with silk-screened markings.

4. Accessory Supplied

4.1 Instruments are supplied with a UL-listed 3-wire power cord. The cord's connectors conform to the American Standard for Grounding Type Attachment Plug Caps and Receptacles. A three-to-two wire adapter is also supplied.

5. Optional Accessory

5.1 Available as an accessory is a step-down transformer, Sprague Electric Type 11-9010-2A, which has a 230 V a-c primary and a 115 V a-c secondary. This transformer is specially designed to provide convenient connectors for using the Model 2W1 Capacitance Meter with 210 to 250 V a-c, 50 to 60 Hz power.

6. Amplifier/Meter

6.1 A self-contained amplifier and meter are used to indicate microfarads.

7. Test Voltage Source

7.1 The 50 to 60 Hz test voltage is taken directly from the a-c power source through the self-contained power transformer.

8. Capacitance

8.1 **Range:** 300 pF to 10,000 μF.

8.1.1 **Fifteen Ranges:** 0 to .001/ .003/ .01/ .03/ .1/ .3/ 1/ 3/ 10/ 30/ 100/ 300/ 1K/ 3K/ 10KμF.

8.2 **Accuracy:** ±3% of full scale.

8.3 **Readability:** 1% of full scale.

9. Maximum C_x Conditions

9.1 **A-C:** (From internal source)

9.1.1 **Frequency:** 50 to 60 Hz, depending upon line frequency.

9.1.2 **Voltage:** 1 volt rms.

9.1.3 **VAR:** 4

9.1.4 **Current:** 4 amperes.

9.2 **D-C:** (From external source)

9.2.1 **Voltage:** 0 to 600 volts.

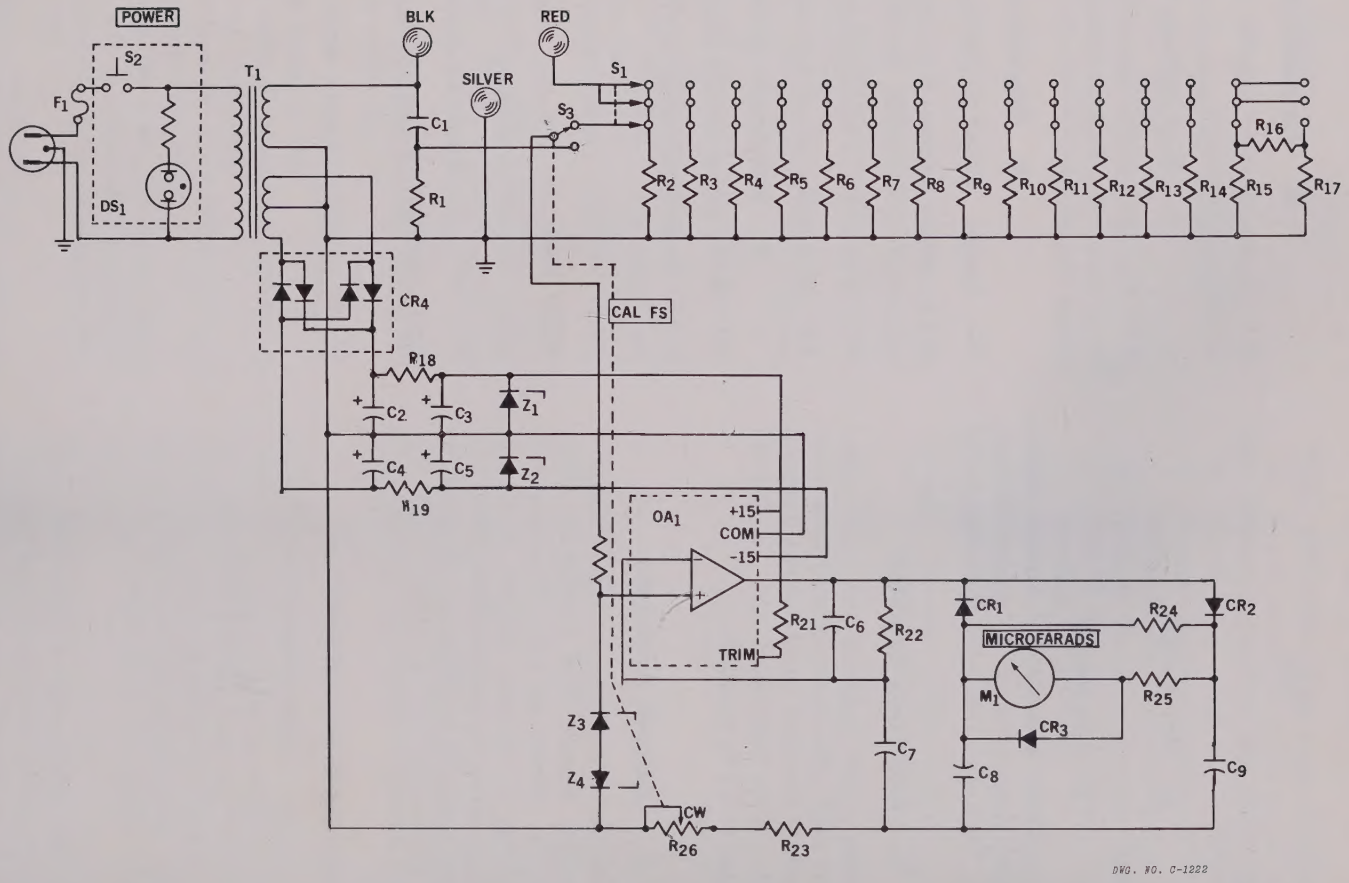
POWER
BLK
RED
SILVER
S2
T1
S1
S3
F1
C1
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
R17
DS1
CR4
CAL FS
R18
C2
C3
Z1
C4
C5
Z2
R19
OA1
+15
COM
-15
TRIM
R21
C6
R22
CR1
R24
CR2
MICROFARADS
M1
R25
CR3
Z3
Z4
C7
C8
C9
CW
R26
R23
DWG. NO. C-1222

Figure 8

Parts List For 2W1 Meter

Circuit Symbol	Replacement Part No.	Description
C_1	50-1268	Capacitor, fixed, Mica dielectric, .009967 μF, $\pm$0.1%, 300Vdc, Sprague Electric Type MDM (special)
C_2, C_3	9015-20	Capacitor, fixed, electrolytic, aluminum, polar, 200μF 50Vdc/200μF 25Vdc, +100 −10%, common-negative, Sprague Electric Type DEE (special)
C_4, C_5	9015-21	Capacitor, fixed, electrolytic, aluminum, polar, 200μF 50Vdc/200μf 25Vdc, +100 −10%, common-positive, Sprague Electric Type DEE (Special)
C_6	9015-16	Capacitor, fixed, ceramic dielectric, .01μF $\pm$20%, 100Vdc, Sprague Electric Type CO-23B101F103M
C_7	9015-17	Capacitor, fixed, electrolytic, solid tantalum, 10μF, $\pm$20%, 15Vdc, Sprague Electric Type 164D105X0015B0
C_8, C_9	9015-18	Capacitor, fixed, electrolytic, solid tantalum, polar, 1μF, $\pm$20%, 15Vdc, Sprague Electric Type 164D105X0015A0
CR_1, CR_2	88-11	Diode, Type 1N54A
CR_3	88-12	Diode, Type 1N1697
CR_4	9010-59	Rectifier, bridge
DS_1	217-68	Lamp, pilot, Neon
F_1	217-69	Fuse, 1/4A-SB, Type AGC
M_1	9010-57	Meter, 50μA d-c
OA_1	9010-58	Amplifier, operational
R_1	9012-F-135T	Resistor, fixed, metal-film, 30.1K ohms, $\pm$0.1%, 25 watt, Sprague Electric Type 419E3012BT2
R_2	9012-147M	Resistor, fixed, deposited-carbon, 300K ohms, $\pm$1%, 1 watt
R_3	9012-147L	Resistor, fixed, deposited-carbon, 100K ohms $\pm$1%, 1 watt
R_4	9012-140J	Resistor, fixed, deposited-carbon, 30K ohms, $\pm$1%, 0.5 watt
R_5	9012-141D	Resistor, fixed, deposited-carbon, 10K ohms, $\pm$1%, 0.5 watt
R_6	9012-140Z	Resistor, fixed, deposited-carbon, 3K ohms, $\pm$1%, 0.5 watt
R_7	9012-140X	Resistor, fixed, deposited-carbon, 1K ohm, $\pm$1%, 0.5 watt
R_8	9012-140S	Resistor, fixed, deposited-carbon, 300 ohms, $\pm$1%, 0.5 watt
R_9	9012-140P	Resistor, fixed, deposited-carbon, 100 ohms, $\pm$1%, 0.5 watt
R_{10}, R_{17}	9012-140J	Resistor, fixed, deposited-carbon, 30 ohms, $\pm$1%, 0.5 watt
R_{11}	9012-140G	Resistor, fixed, deposited-carbon, 10 ohms, $\pm$1%, 0.5 watt
R_{12}	9012-146B	Resistor, fixed, deposited-carbon, 3 ohms, $\pm$1%, 1 watt
R_{13}	9012-151	Resistor, fixed, wirewound, 1 ohm, $\pm$1%, 10 watts, Sprague Electric Type 247E1R01
R_{14}	9012-152	Resistor, fixed, wirewound, 0.3 ohm, $\pm$1%, 10 watts, Sprague Electric Type 247EXR3000F
R_{15}	9012-153	Resistor, fixed, wirewound, 0.1 ohm, $\pm$1%, 10 watts, Sprague Electric Type 247EXR1000F
R_{16}	9012-140M	Resistor, fixed, deposited-carbon, 70 ohms, $\pm$1%, 0.5 watt
R_{18}, R_{19}	9012-155	Resistor, fixed, composition, 1K ohm, $\pm$5%, 1 watt
R_{20}	9012-154	Resistor, fixed, wirewound, 20K ohms, $\pm$10%, 10 watts, Sprague Electric Type 10E2039T8
R_{21}	9012-156	Resistor, fixed, composition, 24K ohms, $\pm$10%, 0.5 watt
R_{22}	9012-157	Resistor, fixed, composition, 220K ohms, $\pm$10%, 0.5 watt
R_{23}	9012-158	Resistor, fixed, composition, 510 ohms, $\pm$10%, 0.5 watt
R_{24}	9012-159	Resistor, fixed, composition, 15K ohms, $\pm$5%, 0.5 watt
R_{25}	9012-160	Resistor, fixed, composition, 620 ohms, $\pm$5%, 1 watt
R_{26}	217-67	Resistor, continuously adjustable, 0→1K ohm, $\pm$10%, 0.5 watt
S_1	217-66	Switch, rotary, 3P15T
S_2	217-68	Switch, positive-action, SPST
S_3	217-67	Switch, momentary-contact, SPDT
T_1	9010-56	Transformer, power (special)
Z_1, Z_2	88-13	Diode, Type 1N3024B
Z_3, Z_4	88-14	Diode, Type 1E9.1Z5

NOTES

Warranty

The Sprague Electric Company warrants each new instrument manufactured by Sprague to be free from defects in material and workmanship, and to perform according to applicable specifications, if properly operated, for a period of one year from the date of original purchase. The Sprague Electric Company's liability is limited to service work performed at the Sprague factory. Specifically excluded from this Warranty are transistors, tubes, bulbs, fuses, and batteries.

Before this Warranty is effective, the following conditions must be met: (1) The warranty registration card must have been returned within 30 days after the date of original purchase, (2) the instrument must be returned to the Sprague Electric Company, (3) Subsequent examination by Sprague must disclose in Sprague's judgment that the instrument is defective within the terms of this Warranty.

This Warranty is in lieu of all other warranties, expressed or implied. If the return of this instrument is deemed necessary, advise the Instrument Department of the Sprague Electric Company in North Adams, Massachusetts, giving full details, including model and serial number. Sprague Electric Company will reply with complete shipping instructions. **No adjustments will be made unless Sprague's permission for the return of the instrument is obtained BEFORE making shipment.**

NOTE: Returned instruments must be packed carefully, marked "Fragile," and shipped prepaid.

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Litho in U.S. Amer.